NATIONAL SECURITY AND EMERGENCY PREPAREDNESS COMMUNICATIONS EXPERIMENTS USING THE ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE

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Many government telecommunications needs, especially those that support National Security and Emergency Preparedness (NS/EP) missions, are becoming increasingly dependent on commercially available equipment and services. This is consistent with the goals and concepts of the National Information Infrastructure. This report examines the use of an advanced satellite–in this case, NASA's Advanced Communications Technology Satellite (ACTS)–with ISDN and frame relay protocols to support NS/EP communications requirements. A network using three ACTS Earth stations was established as a research facility. With this small network, several experiments were performed. Using new objective methods, voice quality was measured over the satellite and compared to other connections such as commercial, terrestrial lines. The performance of applications-desktop conferencing, file transfer, and LAN bridging–that are likely to be useful in NS/EP situations, was determined. The performance of TCP/IP running over frame relay was examined. The results indicate that advanced satellites can be very useful for emergency communications due to the rapidity that Earth stations can be deployed, the ease of reconfiguring the satellite, and the practicality of using commonly available applications running over commonly used protocols. However, there are some limitations to the performance of some applications or parts of applications due to the propagation delay of a satellite channel. Telecommunications protocols such as TCP/IP must be significantly modified to perform well over a satellite channel and to take full advantage of bandwidth-on-demand capabilities of an advanced satellite.

Key words: Advanced Communications Technology Satellite (ACTS); integrated services digital network (ISDN); frame relay; National Security and Emergency Preparedness (NS/EP).

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1. OVERVIEW AND SUMMARY

When a crisis arises, whether natural disaster or threat to national security, there are sudden needs whose rapid fulfillment can mean the difference between life and death and loss of property. These needs include rescue operations, medical aid, law enforcement, and the distribution of food, water, and other supplies. Effective communication and coordination are essential to effectively meet these needs.

Not only the support efforts, but also the cause of the crisis itself places constraints on existing telecommunications facilities. For example, an earthquake not only creates demands far in excess of what is required under normal conditions, but also can sever terrestrial telephone lines. Preparation for and provision of the telecommunications needed by Federal and local authorities during such events is the responsibility of the National Communications System (NCS).

The NCS is responsible for ensuring that Federal Government requirements for National Security and Emergency Preparedness (NS/EP) telecommunications are met. NCS accomplishes this through a variety of programs that: (1) ensure the interoperability and availability of systems by contributing to the development of technical standards, and (2) assist the Executive Office and various Federal agencies with the management and coordination of the nation's telecommunications resources.

In order to continue to meet NS/EP communications requirements, the NCS must take advantage of the emerging high-speed, multifunctional National Information Infrastructure (NII). For the forseeable future, the NII must include satellites in order to provide true national coverage, especially when rapid deployment is needed in an affected area or disaster site. A hybrid telecommunications system comprised of wireless and wireline services augmented with advanced satellites must be considered by NCS to best meet their mission of providing NS/EP communications for the United States.

1.1 National Security and Emergency Preparedness Telecommunications

The mission of the NCS was reaffirmed in a White House Memorandum, dated October 15, 1991. That memo reaffirms that the policy guidance given in Executive Order 12472 and National Security Decision Directive 97 (NSDD-97) still represents the primary mission of the NCS. The memorandum gives the functional requirements of the National Level Telecommunications Program. Specifically, these are:

Voice Band Service	The service must provide voice band service in support of Presidential communications.
Interoperability	The service must interoperate with and use the resources of selected other Government or private facilities, systems, and networks through the application of standards.

Survivability/Endurability	The service must provide for the interconnection of surviving users under a broad range of circumstances from wide-spread damage from natural or manmade disaster up to and including nuclear war.
International Interface	The service must provide access to and egress from international service.
Nationwide Coverage	The service must provide readily available nationwide coverage to support the national security leadership and intra/interagency emergency operations.
Intra/Interagency Emergency Operations	Common user service must provide NSIEP traffic with priority service.

In order to accomplish its mission, the NCS has undertaken a number of important activities and programs. The National Level Program (NLP) and evolutionary architecture have focused on the public switched network (PSN) resources to meet NS/EP telecommunications needs. The Government Emergency Telecommunications Service (GETS) program is a key element of the NLP and has been established to add NSIEP features (e.g., priority treatment) and enhancements (e.g., improved routing) into the various commercial carriers' networks to better accommodate NS/EP user requirements in emergencies.

1.2 Advanced Communications Technology Satellite

The Advanced Communications Technology Satellite (ACTS) provides an experimental prototype of the features and capabilities planned for future communications satellites. ACTS demonstrates two emerging technologies of great potential value to NS/EP communications: spot beams and on-board switching. Successful integration and optimization of these related technologies will enable ACTS-derived operational satellites to provide hundreds of megabits per second of switchable “bandwidth-on-demand” between Earth stations located virtually anywhere in the Western hemisphere. This is a flexibility that no practical combination of redundant terrestrial facilities can equal. Satellite-based switching facilities could be substituted for damaged terrestrial-switching facilities located anywhere in a network. Earth stations could be permanently located at key terrestrial network nodes or could be quickly deployed to other locations when required due to emergency situations. Permanent Earth stations could be used to support operational traffic under normal conditions by improving terrestrial load sharing and by providing much of the revenue needed for their installation and operation.

Satellites are an important element in providing NS/EP telecommunications and restoring of the PSN. As the PSN evolves toward new technologies and as new satellite technologies, such as ACTS, are introduced, the NCS must continue to ensure that NS/EP telecommunications requirements will be met. NCS has already undertaken experiments that demonstrate the ability of the ACTS system to accommodate required NS/EP features (e.g., access security and priority/preemption) and to support voice communications and connectivity between NS/EP users and the PSN. Another aspect, the focus of this study, is to examine some typical, representative NS/EP communications and to determine how well the users' applications work over a satellite network.

1.3 The ACTS Collaboration and Its Goals

The ACTS Collaboration is comprised of the following four Government agencies and private corporations:

1. The National Telecommunications and Information Administration (NTIA), Institute for Telecommunication Sciences (ITS), Systems and Networks Division, Boulder, Colorado.

2. The National Institute for Standards and Technology (NIST), Computer Systems Laboratory (CSL), Gaithersburg, Maryland.

3. COMSAT Laboratories, Network Technology Division, Clarksburg, Maryland.

4. MITRE Corporation, Reston, Virginia.

Each of the collaborators is an official ACTS experimenter, and three of the collaborators have an ACTS Earth station. The formation of this collaboration resulted from two opportunities. One was the ability to assemble a small network that includes the ACTS Earth stations of three of the collaborators and other telecommunications media as shown in Figure 1.1, and another was the unique combination of knowledge and skills represented in the members of the collaboration.

The general goals of the ACTS Collaboration are to demonstrate and, where possible, measure the performance of some commercial off-the-shelf (COTS) equipment and capabilities over ACTS. Each demonstration or measurement represents some aspect of NS/EP communications. Applications experiments include voice communications, desktop conferencing, and LAN bridging. A protocol experiment tested the performance of TCP operating over frame relay using variable (static and dynamic) bandwidth and TCP window size.

The objective of each experiment in the set was to determine the qualitative and/or quantitative performance of satellite communications used in tests similar to what would be needed in actual NS/EP situations. Specifically, this effort demonstrates the feasibility of using an advanced communications satellite system to enhance or replace terrestrial communications facilities, and evaluates the performance of a set of applications as viewed from the users' perspective. The performance data can support analyses and enable conclusions regarding which technology features are most effective and the quality of service levels that can be expected. The results and conclusions are useful for setting minimum performance specifications for advanced satellite communications systems and in defining other requirements for advanced satellite systems supporting NS/EP communications.

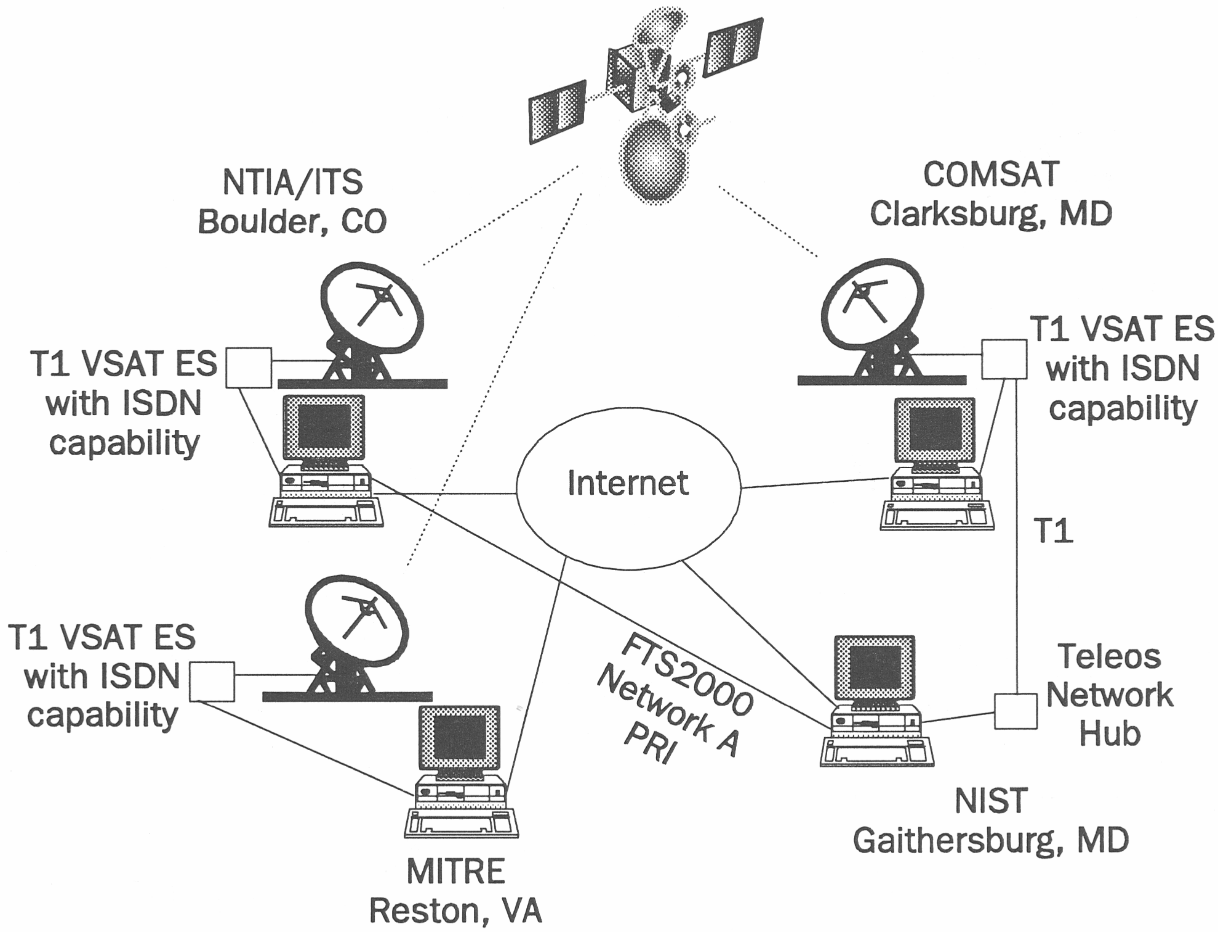

Figure 1.1. The experimental ACTS network.

1.4 The Emergency Scenario

The experiments represented a hypothetical emergency scenario as shown in Figure 1.2. The purposes of the scenario were to provide a fundamental configuration of telecommunications equipment and to define the roles and activities of each site. The Emergency Response Site (ERS), located at NTIA/ITS, represents elements of emergency response organizations that require communication to locations outside the affected area. The Processing Center (PC), located at MITRE, represents some of those locations outside the affected area that can provide support for inquiries into medical records, map databases, insurance forms processing, and coordination for supplies. The Home Office (HO), located at COMSAT and NIST represents regional or national headquarters, and can provide the ERS with additional communications connections such as a LAN or Internet bridge including applications such as E-mail and World Wide Web server access.

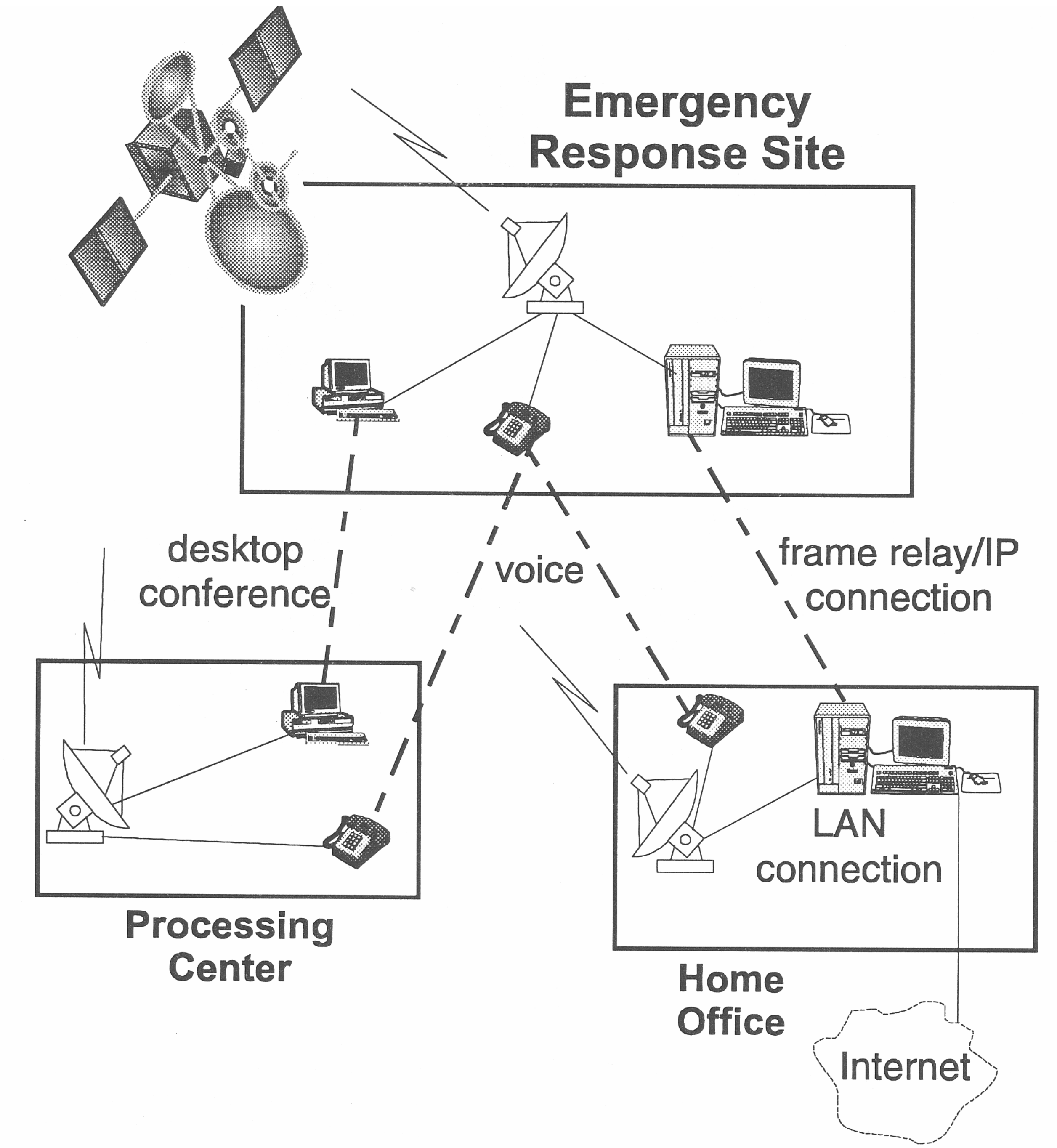

Figure 1.2. Emergency scenario configuration.

The PC and HO, in general, support the ERS with four types of communications services: voice telephone, teleconferencing, desktop conferencing, and data communications.

Voice telephone service is defined as a 64-kb/s link using a local ISDN switch. This type of communication allows for interconnections to the public switched telephone network and is the most used form of communications in emergency situations. In this scenario, a number of voice calls are made between the ERS and the PC or HO. Voice quality is measured using a voice quality assessment system (VQAS).

Desktop conferencing is supported by the PC and includes slow-speed video, voice, and data transfer over one channel. This system uses an ISDN basic rate interface (BRI) for these services. The video operates at a rate of 112 kb/s and can also provide a 640 x 480 video “snapshot” for higher quality still images. Voice communications within this system use a rate of 16 kb/s. Desktop conferencing includes the capability of document sharing.

Data communications between the ERS and the HO include a LAN connection and Internet access at the HO, as well as access to the HO’s computing facilities. Through this connection, ERS personnel potentially have access to e-mail services at HO mailboxes and to the entire Internet, including file transfers, remote log-ins and World Wide Web servers. For example, the LAN connection may be used to download hourly weather updates from the Geostationary Operational Environmental Satellite (GOES) using a browser such as Mosaic® or Netscape®.

Examples of information that might flow between the ERS and the PC include requests for equipment, supplies, and other resources such as food and temporary shelter; medical support requests and medical information; requests for support for damage assessment and hazardous materials situations; damage reports; coordination of emergency response organizations; insurance form processing; and fund transfers. Communications flow through the HO includes information and data that is directly available on-line or from accessible data bases. ERS personnel access this information directly through the LAN/Internet connection provided by the HO. This information could include weather forecasts and weather satellite photographs; geological and geophysical information, activity reports and forecasts; and medical expert systems and databases.

Numerous simplifications have been assumed in order to conduct experiments in a straightforward manner. For example, only a small sample of the possible activities that occur in an emergency situation were examined. In addition, the examination was at a somewhat high level of abstraction. This was done so that the types of information movement that might occur in the applications used in an emergency situation could be determined. These interactions will be affected by the characteristics of the satellite channel in different ways and with different effects on the applications that use them.

Four experiment categories are described in detail in major sections of this report. Three of these are applications experiments that include voice quality described in Section 2, desktop conferencing in Section 3, and LAN bridging in Section 4. The fourth experiment on TCP over frame relay is described in Section 5. The subsections below present conclusions and recommendations that are drawn from the full set of experiments, and some recommendations for future work.

1.5 General Conclusions

For the applications tested-voice communications, desktop conferencing, and LAN bridging–the delay due to the satellite channel is not a significant contributor to reduction of the usability or quality of the applications. Delays due to processing in terminal equipment dominated. This only presents a problem on highly interactive activities, such as the use of the whiteboard function in the desktop conferencing. However, channel bit error rate (BER) is a significant contributor to reductions in usability or quality of the applications unless the bit error rates are less than 10^{-5}.

For the voice communications application, there is little or no difference in voice quality, or intelligibility, across all ISDN connections, including the satellite. All ISDN connections are significantly better than long-distance telephone service.

The quality of all desktop-conferencing components–video, voice, and whiteboard–begins to degrade at a BER of 10^{-6}; they all become unusable at a 10^{-3} BER. Although usable at BER's of 10^{-5}, annoyance factors may be a problem for some users or in some situations. At this level, the audio signal is usable but only in good listening environments, and slow response may make the whiteboard function difficult to use. Generally, the video component degrades more quickly with increasing BER.

Each component in a hybrid network independently contributes to the quality of information an end user receives. This means that a single component can cause severe degradation of quality or even cause a loss of connection. This connection loss was confirmed during the LAN-bridging experiments and desktop conferencing, but can occur for any application. During local generation of errors, although the applications continued to operate, high BER's ($>10^{-3}$) caused the commercial, terrestrial network to terminate the connection due to administrative decision by the communication service provider. Generally, the LAN-bridging applications began to degrade at BER's of 10^{-6} and became unusable for BER's of 10^{-3} and higher. The degradation can be exacerbated for applications that require multiple connections.

Unlike the applications experiments, the TCP/IP over frame relay protocol experiment directly examined the supporting infrastructure; specifically, the support provided by TCP/IP and enhanced TCP (TCP-LFN) as part of the system with no applications. Over the satellite channel, TCP/IP with a default window size of 8 kB supports a peak throughput of less than 100 kb/s with any bandwidth allocation larger than this. Simply increasing the window size will increase the peak throughput to a limit of a few hundred kb/s. If the increases in window sizes are accompanied by a more careful treatment of round-trip times (RTT, needed for retransmission decisions), then the throughput rises to fill the bandwidth–in this case 1.544 Mb/s. Enhanced TCP (TCP-LFN) has a very large window size (2^{31}-1), time-stamps for each packet, and other features.

1.6 Suggestions for Future Work

The experiments and measurements described herein can be extended or built upon to obtain more information about satellite communications. The voice quality experiments of Section 2 show that the ISDN voice channels available over ACTS are of very high quality. In fact, the satellite and terrestrial ISDN channels offered about the same, high level of voice quality. These results can provide a reference for future measurements of voice quality. For example, the quality of a voice channel that must operate with some compression and coding as would occur on a typical low Earth orbit (LEO) satellite could be compared to the voice quality measurements reported here. Indeed, measurements of voice quality can be made in the same manner over any voice communications system; for example, wireless or cellular telephone. Combinations of voice communications systems can be assessed in the same way.

The information gained from the desktop-conferencing and LAN-bridging experiments also provides a reference for any future assessments of similar applications. The protocol experiment can be extended to asynchronous transfer mode (ATM) and could include the use of Internet tools such as e-mail and web browsers to generate traffic. The ACTS will be available for experimentation for about two more years.